Putting the E in STEM
Teaching and Learning

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THE IDEA FOR the “Everyday Engineering” column in Science Scope began with our interest in design and production issues related to the simple ballpoint pen. We were struck by the elegance of the means for retracting the reservoir and transferring the ink to paper. There are many engineering and science concepts involved in these processes. Almost all ballpoint pens work the same way. And some are sold for as little as 19 cents. This led to the development of an activity we used with our students and then a workshop at the Detroit NSTA Regional Conference in the fall of 2007. The pen material was published as “Everyday Engineering: What Makes a Bic Click?” (see Chapter 2) in the April/May 2009 issue of Science Scope. Another workshop was presented at a McGraw-Hill Science and Technology Symposium for science supervisors from across the country. The feedback from both teachers and administrators was overwhelmingly positive. We realized that others, too, shared our zeal for appreciating the engineering of simple, common, everyday devices.

For some months, we found ourselves taking a number of things apart—becoming more and more intrigued with the design of the seemingly simple. When thought about in this light, paper clips and pump soap dispensers become fascinating. Learning the history of how these everyday objects were developed is also fascinating. We then proposed to Inez Liftig, the editor of Science Scope, a regular feature called “Everyday Engineering” that would investigate the science and engineering of simple, everyday items. This proposal was quickly endorsed by Inez and the Science Scope Advisory Board. In order to provide teachers, scout leaders, workshop leaders, parents, and engineers leading outreach activities with the collection of “Everyday Engineering” ideas, this book was conceived.

We envision that Everyday Engineering: Putting the E in STEM Teaching and Learning can be used in a number of different ways. Since the new A Framework for K–12 Science Education (NRC 2011) includes engineering as a disciplinary core idea, teachers may use our book to integrate the engineering concepts within their normal science curriculum. Other teachers may wish to teach one or more separate engineering units. After-school group leaders, summer enrichment program administrators, and even youth group leaders may choose to use the activities as well. We also hope that parents who wish to share the world of engineering with their children will find this book to be beneficial since each activity is complete, includes safe procedures, and explains the science and engineering concepts involved as well as the history and development of the everyday object’s design.


Reference
ACKNOWLEDGMENTS

THE AUTHORS ARE indebted to our students for their enthusiastic willingness to engage in the classroom activities we present. The feedback we receive is of great value. We are also appreciative of sixth-grade science teacher Cindy Pentland and her middle-level students in metropolitan Detroit. They were ready to try out our engineering activities on a regular basis and were always eager to get their hands on everyday devices and their minds involved in how things work. In addition, Samantha Hartshaw and Leah Walkuski, two of our student assistants, provided much help working through many of the activities in Ms. Pentland’s classroom.

We also want to recognize our colleagues at the Inquiry Institute at the University of Michigan–Dearborn. Specifically, we want to thank Chris Burke, John Devlin, Charlotte Otto, Steve Rea, and Paul Zitzewitz for their willingness to talk with us about our ideas.

Finally, we are indebted to our editors at Science Scope: Editor Inez Liftig, Managing Editor Ken Roberts, and Consulting Editor Janna Palliser. Their good work makes us better. They work tirelessly to make Science Scope such an outstanding classroom aid to its thousands of readers. We are also grateful for the work done by Claire Reinburg, director of the NSTA Press and her outstanding staff, especially Agnes Bannigan, who was responsible for putting this volume together so seamlessly.
THE FLASHLIGHT IS often unappreciated until the electricity goes out. We all reach for one and hope that the batteries are still good. The flashlight is a simple device that is composed of a lightbulb, usually two cells connected in series, a housing, a switch, and a reflector for the light. All flashlights essentially use these parts to complete a circuit that converts the stored chemical energy in the cells to light energy.

In this lesson, students will take apart an inexpensive flashlight (less than $2 with D-cell batteries) to determine how the parts work together to produce light. Students will then make a flashlight of their own design using common household materials. While constructing a simple circuit with a switch is straightforward, putting it all together as a device is likely to challenge students. Many middle level students may have little experience designing and building something on their own. The ITEEA recommends that students understand the core concept of dealing with malfunction: “Malfunctions of any part of a system may affect the function and quality of a system” (2002, p. 39). In the case of a flashlight, there are many possible reasons why it may fail (malfunction)—a burned out bulb, a dead cell, or a poor connection, to name a few. Resolving problems while building something may be difficult for some students; consequently, you may need to encourage them to be analytical in their attempts to problem solve. Like all lessons in the book, this one follows the 5E Model.

The science content of this lesson focuses on simple circuits and the transfer of energy from one form to another: “Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced” (NRC 1996, p. 155). It is recommended that students have a basic understanding of simple electrical circuits before attempting this lesson. If you need ideas for a review of switches and simple circuits, please see Hoffman and Stong (2002); Concannon, Brown, and Pareja (2007); and Sapp (1999).

Historical Information

The flashlight epitomizes the engineering principle of taking advantage of recent discoveries to invent new devices that people can use to solve problems. The essential parts of the flashlight—dry cell batteries and lightbulbs—were both invented in the late 1800s. The lightbulb was invented by Thomas Edison in 1879, and the dry cell was invented by Carl Gassner in 1888 (Schneider 1996). Prior to the invention of the flashlight, people used lanterns or candles for portable
The first commercial flashlight became available in 1896 and was marketed by Conrad Hubert, who had a business selling electrical novelty items such as electric tie tacks and stickpins. The cells were weak and the early bulbs that used carbon fiber filaments were dim, so the lights could only be flashed on for a short time, which gave rise to the term flashlight.

Investigating Flashlights (Teacher Background Information)

Engage

Safety note: Review safety rules with your students for working with batteries, bulbs, and wires before starting this activity. Safety goggles should be worn for the entire activity.

For the Engage activity, each group of two to four students will need an inexpensive flashlight (check your local dollar store for models that use two D-cell batteries). Do not use rechargeable cells because they produce more current and can become dangerously warm if short-circuited. When batteries die, they should be recycled according to local hazardous-waste protocol, not thrown in the trash. In most states, common carbon-zinc cells are not considered hazardous waste.

Prior to the activity, initiate a discussion by showing students a flashlight and inquiring about their previous experiences and prior knowledge. Focus the discussion on how a flashlight works and the circuitry involved. Have the groups disassemble and diagram their flashlights. Usually, inexpensive flashlights have a metallic strip that completes, makes, and breaks the circuit to turn the lamp on and off (Figure 12.1). Allow 10–15 minutes for this initial investigation. Have students put flashlights back together so that the flashlights may be used again with subsequent classes.

Explore

Allow most of a class period for constructing and comparing student flashlights. Provide the following materials for each group or pair of students to make a circuit similar to the one found in a flashlight: two D-cell batteries, a flashlight bulb, electrical tape, and two pieces of bell wire with the ends stripped. A switch can be fashioned out of two paper fasteners, a piece of cardboard, and a paper clip (Figure 12.2). Be sure all students understand this simple circuit before proceeding to the construction of a flashlight. At this point, provide a variety of materials for students to use in making their flashlights. Paper towel (or toilet paper) tubes can be used for the body. Because students may wish to keep their flashlights, instruct them to bring tubes prior to the activity. Bulb holders can be made from small plastic cups (89 ml or 3 oz.) or the top portion of half-liter water bottles. Aluminum foil can be used to make reflectors. Additional typical schoolroom supplies, such as glue, rubber bands, and the like should be provided. Provide a tray of supplies for each group of two to four students. Some groups may ask for additional wire depending on their design. Sample student flashlights are shown in Figure 12.3.

Again, have students make a sketch of their design that explains how the circuitry functions. Students can
add arrows to their sketch to show the flow of energy through the flashlight. The dry cells contain stored chemical energy that changes to kinetic energy in the form of electric current, which is transformed into light and thermal energy as it passes through the high resistance of the filament in the lightbulb.

**Explain**

Have students compare their sketches of the manufactured flashlight with their own designs. The circuits will likely be very similar, unless an unusually creative design was employed. However, they may also differ in a number of ways. For example, most commercial flashlights use a metallic strip and a spring, rather than wires, to complete the inner circuitry. Also, the switch will usually slide and the actual connections are inside the flashlight. Depending on the creativity of the student designs, there may be additional differences, as well.

Students are likely to encounter a number of problems (malfunctions) as they construct the flashlights. Common problems include holding the bulb in place, loosening wire connections, mating the tip of the bulb to the end of the cell, and improper aligning and ordering of the cells. Have students share their flashlights with the class and explain and demonstrate how they work. Such sharing helps to create a learning community that enables students not only to share with one another but also to see creative solutions to problems that they may not have considered themselves. Indeed, this is the same process that engineers (and scientists) experience when they deliver papers at conferences and publish their work in journals.

**Extend**

Gather an assortment of different types of flashlights—Maglites, lantern battery-style lights, penlights, small LED flashlights, etc. (See Figure 12.4 on page 90.) Have each group examine one of the flashlights to determine how it works. These flashlights can be reused for each of your classes. Some flashlights may have a push-button switch, some may have a twist switch, and others will have a sliding switch like the ones used in the activity. The flashlights will also use different types of batteries—the lantern style uses a 6-volt battery, the penlights may use AA- or AAA-cell batteries, and some
may use C-cell batteries. Small LED lights often use button cells. Once again, have students draw a sketch to show the circuitry in their flashlight. Students can also draw their sketches on a transparency so that they can discuss each flashlight type with the entire class. You may also wish to have students conduct some research on the history of flashlights (see Schneider 1996). In addition, students could research flashlights that are used for special purposes—red LED flashlights are used for night vision, as well as for military purposes.

To further extend the lesson, you may want to have students compare a two-cell LED flashlight with a two-cell regular penlight to see if the LED light uses less current. Put fresh cells in each and leave them on until the cells are depleted. You could also calculate the ratio of cost to time for each so that students can see that, eventually, the more expensive LED light is actually cheaper.

**Evaluate**

Show students a 9-volt battery and ask them to design and draw a sketch of a flashlight that uses a 9-volt battery. Have students label the main parts of their flashlight plan and write a short explanation of how it works. The drawings should show the circuitry, including a switch that will enable the bulb to be successfully turned on and off. If students have not had much experience with designing, it is not recommended to base a grade on the creativity of the design. As students gain experience and confidence in trying out their own ideas, you will begin to see a greater variation in student designs. Note: It is not recommended that you have students actually build 9-volt flashlights because you will need higher-voltage bulbs. Due to the proximity of the terminals, it is more likely for students to create a short circuit that may become quite warm.

**Conclusion**

Engineering is often about the simple devices that we take for granted in our everyday lives. The invention of flashlights allowed people to ride bicycles at night, search in dark closets, and move around safely during power outages (Schneider 1996). While there have been improvements in cells, bulbs, and switches, the design of the basic flashlight has changed little in over 100 years, especially when compared to changes in other technologies—air travel from the Wright brothers to the space shuttle, for example.

**References**


Moyer, R., J. Hackett, and S. Everett. 2007. *Teaching science as investigations: Modeling inquiry through*
A LITTLE (FLASH) OF LIGHT

Safety note: Students should wear safety glasses during the activity.

Engage
1. Carefully take apart a flashlight to determine how it works. Caution: Do not attempt to take the cells or the lightbulb apart.
2. How are the parts connected in order to make a complete circuit?
3. Make a sketch of your findings that shows how the bulb lights. Be sure to include how it is turned on and off.
4. Now that you have examined a manufactured flashlight, how would you design your own?

Explore
1. Construct a circuit with two cells in a series that will illuminate a lightbulb.
2. Add a paper-clip switch to your circuit to turn the bulb on and off.
3. Using the materials provided by your teacher, design and then construct a flashlight. Your flashlight should include a switch. Exercise caution with sharp objects and projectiles.
4. Make a sketch of how your flashlight works. Show how it is turned on and off, as well.
5. Trace the path of the energy flow in your flashlight, starting with the stored energy in the cells.

Explain
1. Compare the two sketches of the manufactured flashlight and the one of your own design. How are they the same? Different?
2. What problems did you encounter trying to build your flashlight? How did you solve these problems?
3. Share your flashlight with the class. Demonstrate how it works. What problems did other students encounter and how did they solve these problems?

Extend
1. Look at the different flashlights that your teacher has provided.
2. Take one flashlight apart to determine how it works, including how it is turned on and off.
3. Draw a sketch that shows the circuitry in this flashlight and share it with your class.

Evaluate
Your teacher will show you a 9-volt battery. On paper, design a flashlight using this battery. Show and include a switch in your plan. Label all of the parts.


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“The idea for Everyday Engineering began with our interest in design and production issues related to the simple ballpoint pen. We were struck by the elegance of the means for retracting the reservoir and transferring the ink to paper. ... For some months, we found ourselves taking a number of things apart—becoming more and more intrigued with the design of the seemingly simple. When thought about in this light, paper clips and pump soap dispensers become fascinating. Learning the history of how these everyday objects were developed is also fascinating.” —From the introduction to Everyday Engineering

Here’s an ideal way to spark students’ fascination with the marvels of engineering behind the seemingly simple. This book is a compilation of popular “Everyday Engineering” columns from NSTA’s middle school journal, Science Scope. The collection is made up of 14 activities that explore engineering’s role in five areas: the office, the kitchen, the bathroom, electricity, and outdoor recreation. Students can perform hands-on investigations of objects they use all the time, asking questions such as

- What makes a Bic click?
- Why do squirt guns squirt?
- What makes a better cereal box?

Each activity includes a clear explanation of the science and history behind the object’s development plus a materials list, student data sheets, and safety suggestions. The collection is useful to classroom teachers as well as scout leaders, engineers leading outreach activities, after-school and summer enrichment program staff, and parents.

Everyday Engineering may soon have your students taking a number of things apart—and putting together a lifelong interest in engineering.